Olympia oysters: Where have they gone, and can they return?

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Abstract

Though tribal harvest traditionally occurred, Washington's commercial fishery for the native Olympia oyster (*Ostreola conchaphila*) began only after settlement in the 1850s. By the late 1800s, oysters required protection in a network of State Oyster Reserves. Since then the oyster has remained rare, and both aquaculture and reserve management priorities have shifted to an introduced species (Pacific oyster, *Crassostrea gigas*). A review of Olympia oyster management history demonstrates the commercial overexploitation of oysters, and added harm from water pollution, invasive competitors and predators, and habitat loss. Recently, interest has grown in Olympia oyster restoration, yet little information is available on how to alter habitat to encourage natural recovery. For this reason, we compared recruitment on bare tideflat and five distinct substrates. An experiment was set up at the North Bay Oyster Reserve on Puget Sound in May 2004. Recruitment improved at low elevations and on shell, with the greatest abundance on Olympia oyster shell, followed by live Olympia oysters, whole Pacific shell, crushed Pacific shell, gravel, and bare tideflat. Olympia shell provided a better recruitment substrate than gravel, but shell treatments could not be distinguished statistically. Altogether these findings are broadly applicable to Olympia oyster management and restoration efforts, and also highlight the unique history of Washington's native oyster.

Introduction

Washington State's only native oyster (Olympia oyster, *Ostreola conchaphila*) supported a vibrant fishery during the early history of the state. Archaeological and ethnographic evidence indicates that Native American tribes harvested the oyster for centuries, and with settlement of the region in the mid 1800s, commercial extraction began (Steele 1957; Lloyd 1996; Hutchinson 193-). Oysters were taken from natural reefs in Willapa Bay and shipped on schooners to San Francisco, where they met the demands of an influx of Easterners during the Gold Rush (Dumbauld et al 2003; Lloyd 1996). However, these early shipments resulted in overharvest of natural beds, and by the 1880s, Olympia oyster populations in Willapa Bay dwindled (Hutchinson 193-). The oystermen relied on stocks built up over time, and shell was removed with harvest, hindering recruitment to replenish stocks (Dumbauld et al 2003; Lloyd 1996).

Oyster conservation became one of the first measures addressed after statehood was granted in 1889. Putting into place one of the first systems of marine protected areas, the legislature provided for the protection of natural oyster beds in a network of State Oyster Reserves established between 1890 and 1910 (Westley et al 1985). These initial reserves included some 11,239 acres in Willapa Bay and 4,500 acres in Puget Sound, though today only 10,000 acres remain in Willapa Bay and 1,000 acres in Puget Sound due to lack of effectiveness and interest (Cook et al 1998; Westley et al 1985). Rights to tidelands were also regulated by the Bush and Callow Acts, which allowed oyster growers to cultivate oysters, rather than harvesting the common beds (Steele 1957; Dumbauld et al 2003).

Despite these efforts, the oyster has remained rare. In the early 1900s a substantial industry was maintained in Puget Sound through use of dike cultivation, which protected oysters from temperature extremes and increased production (Hutchinson 193-; Steele 1957). Beginning around the 1930s, though, Puget Sound's Olympia oyster population declined. A number of factors contributed to this reduction, which eventually destroyed the industry (Eaton 1975; Steele 1957). Sulfite waste pollution, municipal sewage, and runoff degraded water quality and reduced reproductive success (Steele 1957, Eaton 1975). Additionally, with declining water quality, commercial and state management emphasis shifted to the Pacific oyster (*Crassostrea gigas*) introduced from Japan (Cook et al 1998; Dumbauld et al 2003). The Pacific oyster is a larger species that grows faster and is less sensitive to water pollution (Steele 1957). Today State Oyster Reserves are not actively managed for Olympia oysters, and rather clams and Pacific oysters are priorities (Cook et al 1998; Westley et al 1985; Bradbury pers. comm.). Commercial interest in the native oyster has likewise fallen to only a few growers (Cook et al 1998).

Recently, interest has grown in Olympia oyster restoration among state agencies, tribes, oyster growers, and nonprofit organizations. Reestablishment of populations could improve water quality, provide habitat for other species, and potentially allow recreational or low levels of commercial harvest, serving the needs of a range of interests. Current restoration efforts are community projects, and practices involve hatchery production and transplanting small oysters to suitable sites (Dumbauld 1999; Peabody pers. comm.). Gravel and Pacific oyster shell have been placed on tideflats to encourage natural rebuilding of populations by enhancing recruitment (Peabody pers. comm.). However, little information is available on how to alter habitat to encourage recovery.

To address this issue, we compared recruitment on bare tideflat and five distinct substrates. The experiment was set up at the North Bay Oyster Reserve, located on Case Inlet in Puget Sound. North Bay is one of the remaining State Oyster Reserves in Puget Sound, as many were sold partially or entirely. Though historical records of the reserve indicate that it was only marginally productive, today the site hosts one of few dense natural populations (Cook et al 1998). The goal of the project was to explore techniques to improve the success of restoration efforts.

Methods

A site was selected within the Olympia oyster reef at North Bay in an area of low oyster density. Thirty 1 m^2 quadrats were arranged in three rows of ten, with rows separated by approximately 50 meters and located between +0.3 m and –0.3 m relative to mean lower low water. Quadrats were spaced 2 m apart within rows. All quadrats were surveyed on May 20, 2004 to record starting percent cover of shell, sand, silt, Olympia oysters, and barnacles. The number of Olympia oysters was also recorded. The following day all quadrats were cleared of shell, oysters, barnacles, rocks, and all other cover down to bare substrate.

Five replicates of each of six treatments were randomly distributed among the 30 quadrats. Substrate treatments involved addition of live Olympia oysters (collected from North Bay immediately prior to treatment), clean Olympia oyster shell, whole Pacific oyster shell, crushed Pacific oyster shell, clean pea gravel, or no addition (bare). The appropriate substrate was spread so as to completely cover the surface of the quadrat.

We tested the effect of substrate on the accumulation of new Olympia oyster recruits during the summer reproductive season. Observations were taken on three occasions to assess dispersion of the substrate from quadrats and the accumulation of silt and macroalgae (primarily ulvoids). On October 16, 2004 substrate was collected from a 1/16 m^2 area, randomly selected within each quadrat. All substrate, whether placed there or accumulated from dispersion, was taken from the area.

Recruit abundances were determined for each 1/16 m^2 section by visual examination of all pieces of substrate down to a prohibitively small size. Substrate was gently rinsed with regular tap water to remove excess silt and sand, and a dissecting microscope was used to locate recruits on all sides of substrate pieces. Dead recruits, usually consisting of lower valve only, were distinguished and recorded separately from live. Size (longest measurable dimension) was estimated for all live recruits. The total number of pieces of substrate examined was also noted for each sample.

In this experimental design, two factors could potentially influence number of recruits observed in October: tidal elevation (row) and substrate type. We tested for main and interactive effects by analysis of variance, with row as a continuous and substrate as a discrete fixed factor (JMP statistical software). Recruit numbers were log-transformed prior to analysis, because raw data showed heterogeneous variances. If treatments influence recruitment, this should appear as significant effects on the total number of recruits (live + dead). However, treatments could alternatively affect post-recruitment survival rather than arrival of larvae, so only live recruits would show treatment effects.

Results

The total number of recruits per sample ranged from 0 to 52 spat in 1/16 m^2. Much of this variation was explained by row and substrate type (Fig. 1, 2). Recruitment improved at low tidal elevations ($F = 18.9$, $P = 0.002$), with each row containing about two additional recruits per sample. Recruitment also varied significantly among substrate types ($F = 5.5$, $P = 0.002$), but the interaction between elevation and treatment was not significant. Post-hoc tests (Tukey's HSD) indicated that more oysters recruited to Olympia oyster shell than gravel or bare areas, and recruitment to shell substrates exceeded the number on bare ground (where small amounts of hard substrate appeared). Recruitment to the four shell substrates could not be distinguished statistically, but the following trend existed: Olympia oyster shell > live Olympia oysters > whole Pacific shell > crushed Pacific shell.

Variation in recruit abundance showed no clear correlations with the survey data for cover of sand and silt or the initial Olympia oyster abundance in the quadrats (Fig. 3, 4). Somewhat higher abundances were observed in quadrats with high percent coverage of silt. However, higher silt abundances were predominately found in the row of lowest tidal elevation, and high sand abundances in the row of highest tidal elevation. Slightly higher abundances were observed in quadrats with high initial Olympia oyster abundance, but significantly higher initial abundances were also noted in areas of low tidal elevation.

The abundance of dead recruits also varied between rows (Fig. 5). The row of lowest tidal elevation had, on average, the highest abundances of dead recruits, while the row of highest tidal elevation had the lowest average number of dead recruits. These trends parallel the abundance of total recruitment, suggesting that the pattern is not the consequence of differential post-recruitment survival, but rather differential recruitment.

For live recruits, the average size (length of longest measurable dimension) was 2.9±0.2 mm over all quadrats. The distribution of sizes is depicted in the histogram in Figure 6. Small recruits were far more abundant than large, which were found in extremely low numbers. Recruit sizes were tightly clustered with few outliers.

Discussion

In this experiment, Olympia oyster recruitment was sensitive to both tidal elevation and substrate type (Fig. 1, 2). Because treatment effects were observed for total recruits, but not dead recruits, tidal elevation and substrate type apparently determine a larva's choice of where to settle, rather than post-recruitment survival, at least across this range. A clear trend of higher recruitment at lower tidal height is evident for all substrate types. Comparisons of the various substrate types are more ambiguous, but indicate that oyster shell is more effective than gravel or bare tideflat, and that Olympia oyster shell will be most effective for restoration. Together these trends suggest that environmental considerations must be accounted for in addition to substrate modification if restoration efforts are to be successful, and a combination of low tidal elevation and addition of Olympia oyster shell will likely yield the highest abundance of spat.

The tidal range considered in this study was small (~ 1 m), but this environmental trait appeared much more important than sediment type (silt vs. sand). However, further studies may reveal trends in the success of larvae recruitment based on sand, silt, or shell abundance, or as related to the combination of substrate addition and the underlying tideflat characteristics. The trend towards higher spat abundance in areas with high initial Olympia oyster abundance is likely an artifact of higher initial abundances at lower tidal elevation. This supports the finding that tidal elevation is critical to successful larval recruitment.

Recruits observed from the October collection were very small in size, suggesting settlement in late summer, which was unexpected. Historic documents and personal accounts (Bloomfield pers. comm.) indicate that Olympia oysters typically settle in spring, and this year settled in late May. The limited variation in size indicates that a recruitment peak occurred late in the season. Low numbers of large recruits do not reveal an early peak, but it is possible that recruitment began before substrate was placed at North Bay in mid May. Olympia oyster recruitment was measured in 2004 in North Bay independently, based on recruits to shellstrings suspended just above the sediment (Buhle unpublished). Recruitment was low until the end of June, and increased during July. Low recruitment was observed during August. Data are not available for September. It may be the case that the small recruits observed in the substrate experiment are from the July settlement peak, or they may have recruited in September after shellstrings were removed. Given the variable nature of Olympia oyster reproduction, we recommend further study of these recruitment-timing trends.

As efforts proceed, restoration techniques for Olympia oysters in Washington State should be evaluated for their efficacy and the existence of unexpected consequences for oyster habitat or for other species or ecosystem processes. Based on our findings, it appears that substrate modification can be an effective restoration tool for Olympia oysters. Other factors influencing restoration success, including predation, competition, water quality, and harvest levels remain to be addressed.

Figures

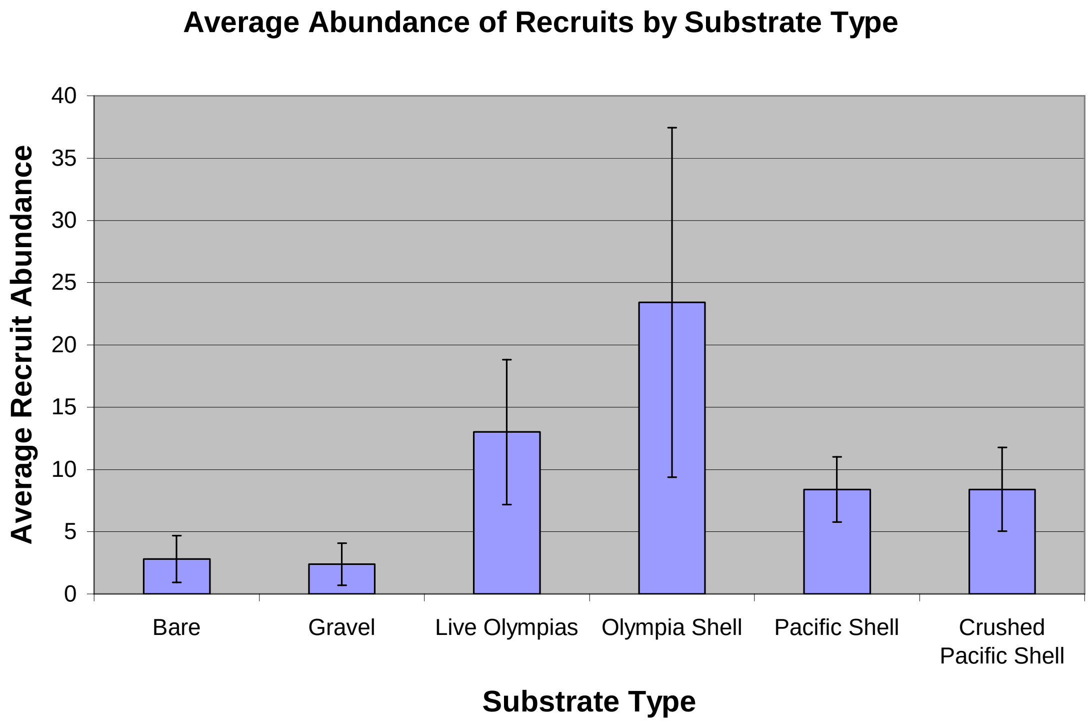

Figure 1. Average Abundance of Recruits by Substrate Type. Abundances include total of live and dead recruits. Standard error bars are shown for raw data, but statistical analyses were carried out on log-transformed data.

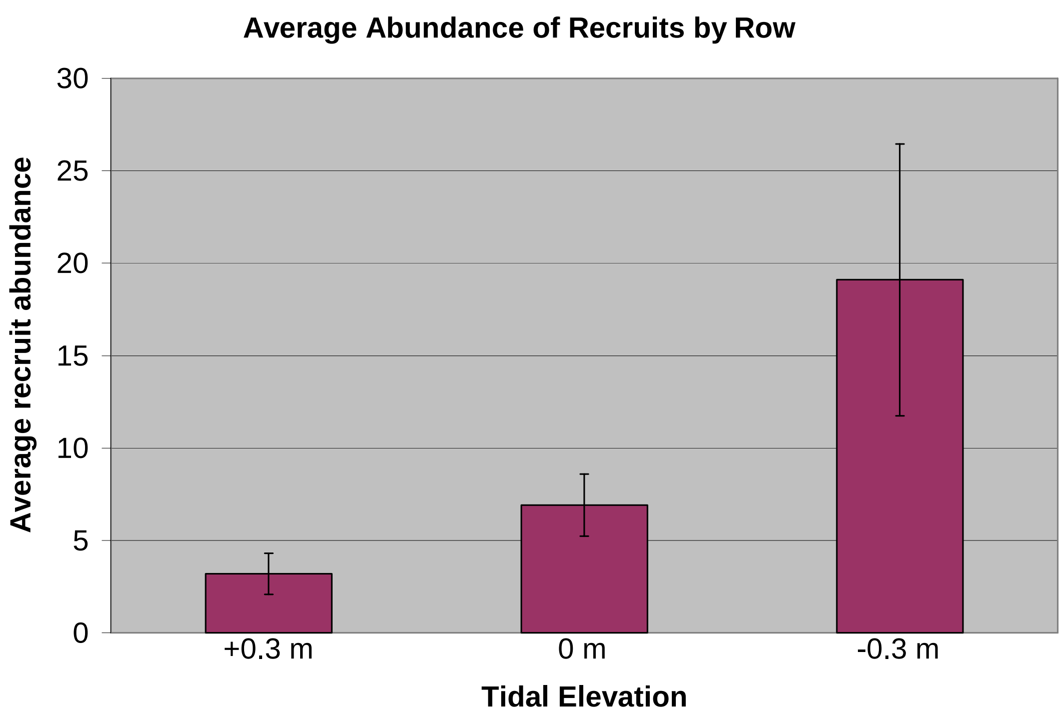

Figure 2. Average Abundance of Recruits by Row. Abundances include total of live and dead recruits. Standard error bars are shown. Tidal elevation is relative to mean lower low water.

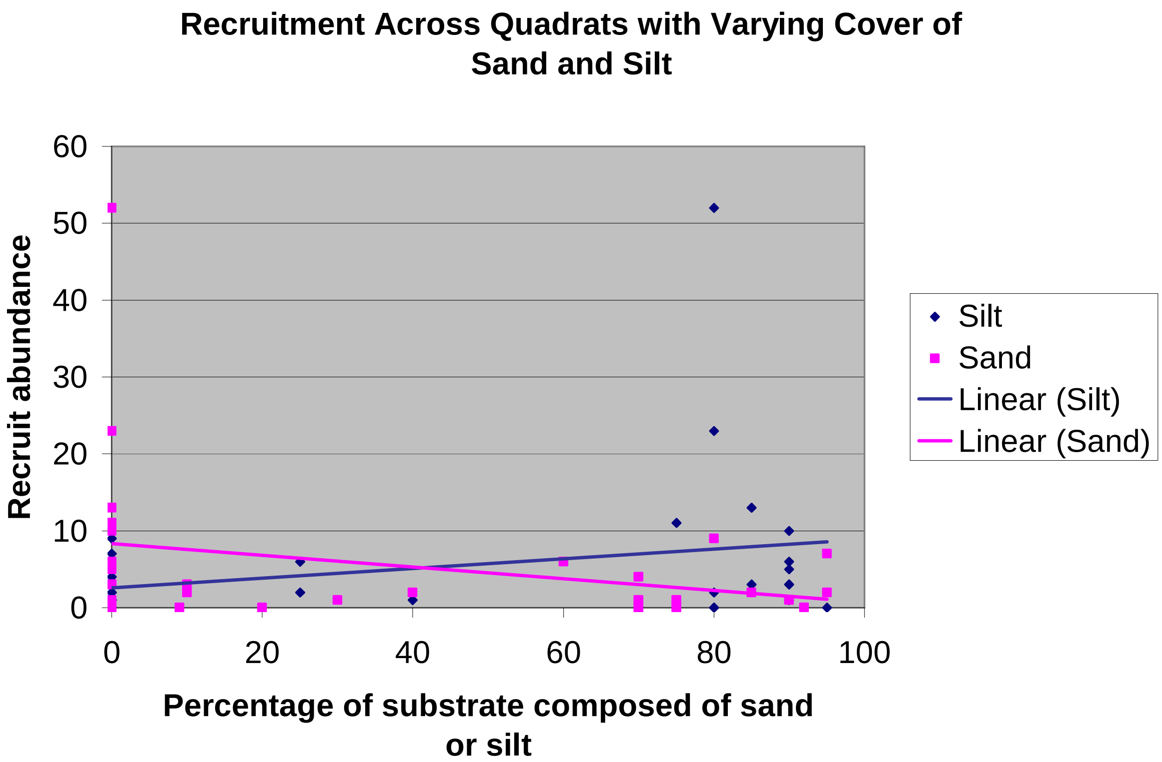

Figure 3. Recruitment Across Quadrats with Varying Cover of Sand and Silt. Abundances include total of live and dead recruits. Best-fit lines are shown.

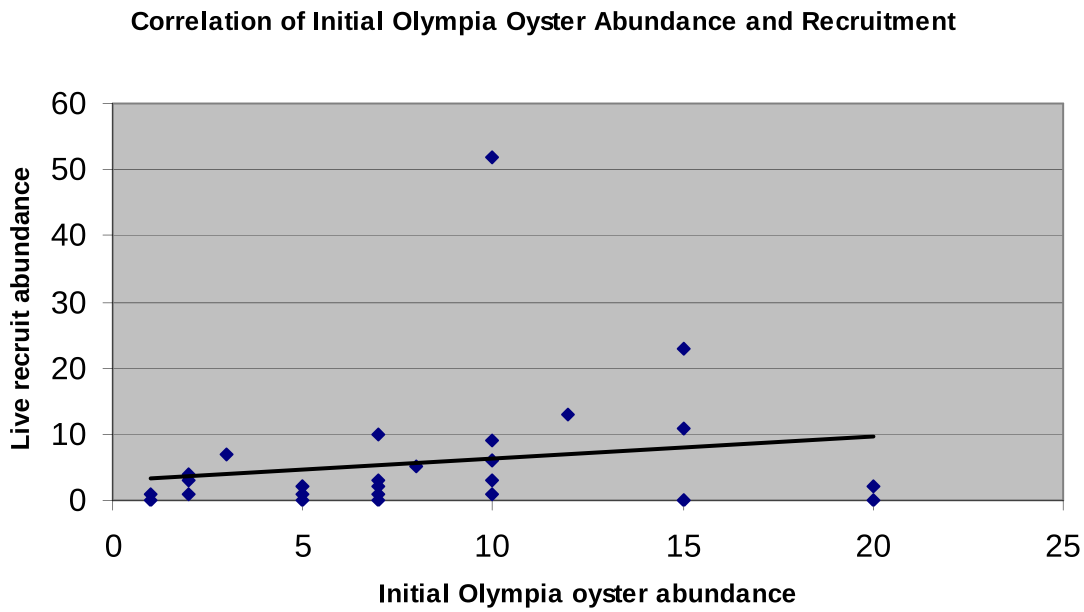

Figure 4. Correlation of Initial Olympia Oyster Abundance and Recruitment. Abundances include only live recruits. Best-fit line is shown.

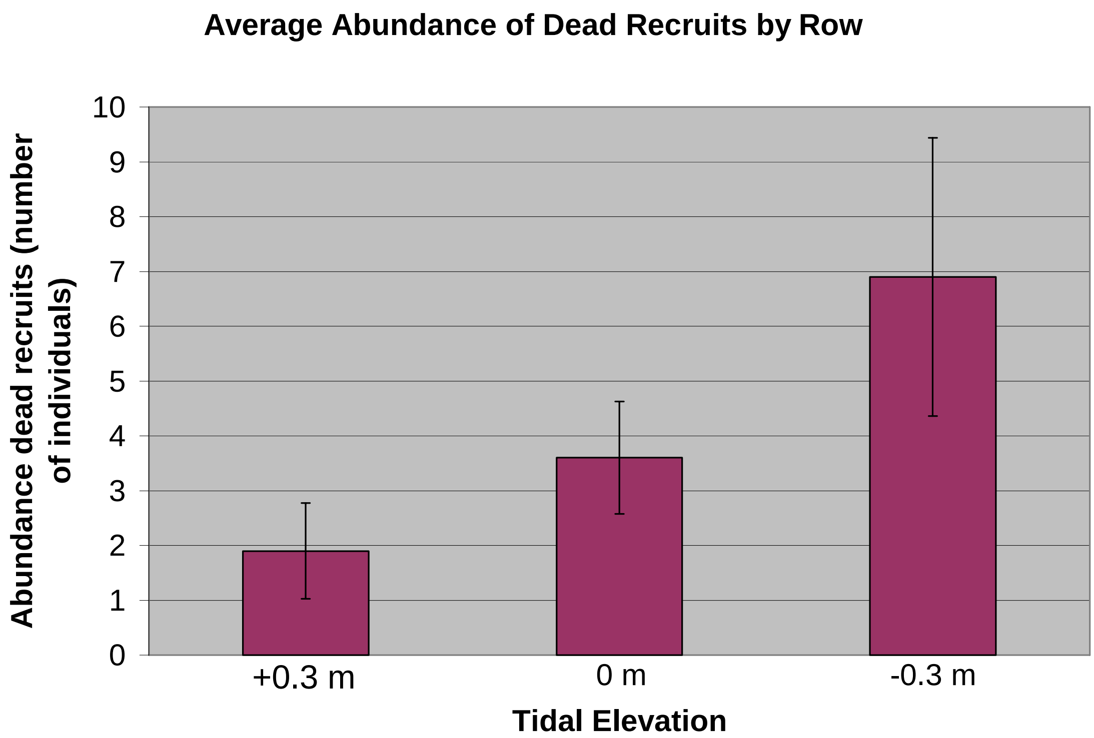

Figure 5. Average Abundance of Dead Recruits by Row. Abundances include only dead recruits. Standard error bars are shown.

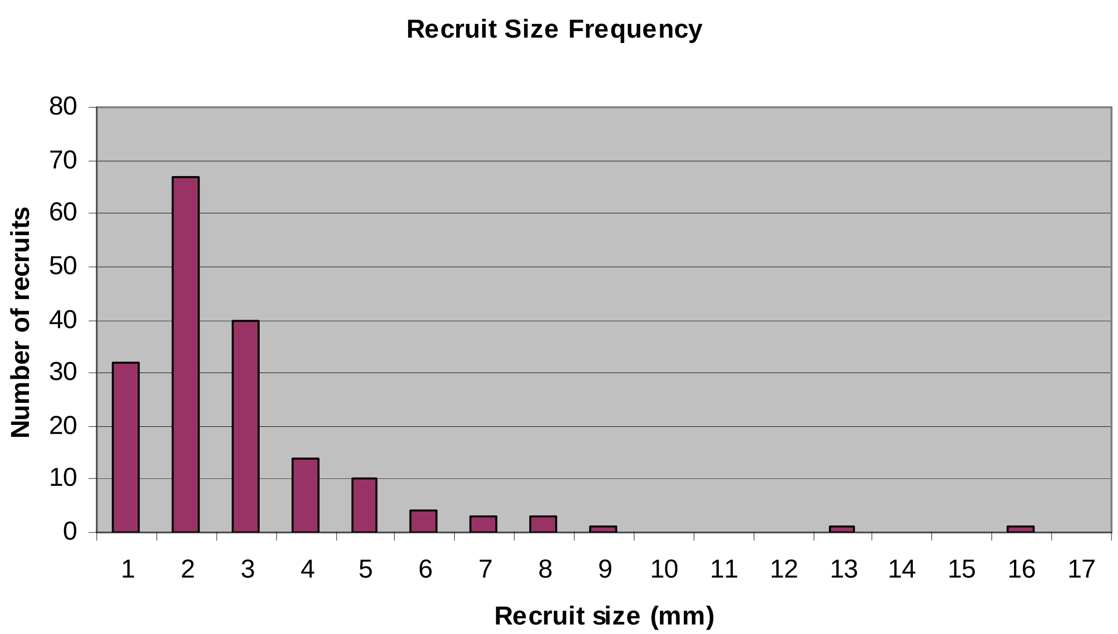

Figure 6. Recruit Size Frequency. Abundances include only live recruits. Measurements were made of the longest measurable dimension.

BACK

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